

# PACT Stress Testing Protocol

Version 0.1

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## 1. Introduction

The purpose of this protocol is to use accelerated stress testing to assess the durability of metal halide perovskite (MHP) photovoltaic (PV) modules. The protocol aims to apply field relevant stressors to packaged MHP modules to screen for early failures that may be observed in the field. The current protocol has been designed with a glass/glass-PIB edge seal, no encapsulant package in mind. PACT anticipates adding additional testing sequences to evaluate additional stressors (e.g., PID, reverse bias) in the future.

*Disclaimer: the initial version 0.0 of this protocol has not been tested or validated against field failures. The initial protocol has been designed with inputs from IEC61215:2021, the MHP ISOS protocols, and input from the community. This protocol will be revised as updated as PACT tests the approach and validates against field data*

## 2. Definitions and References

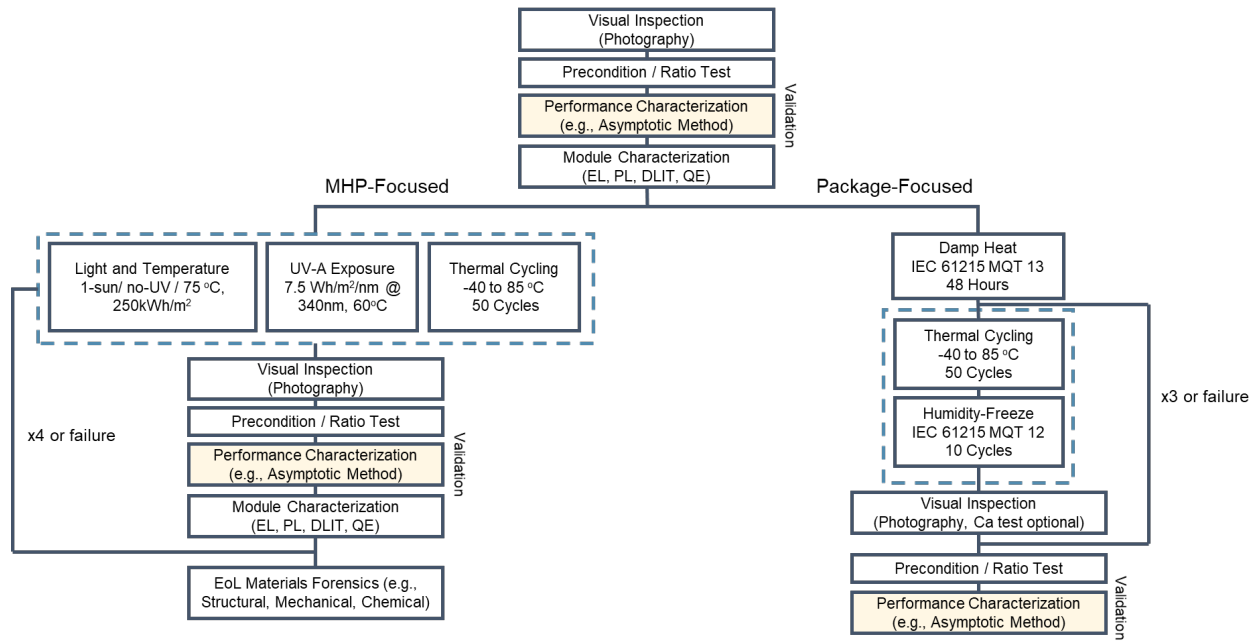
- MHP: Metal Halide Perovskite
- PV: Photovoltaic
- IEC 61215:2021: defines requirements for the design qualification and type approval of terrestrial photovoltaic (PV) modules suitable for long-term operation in general open-air climates
- MHP ISOS protocols: “Consensus statement for stability assessment and reporting for perovskite photovoltaics based on ISOS procedures” <https://doi.org/10.1038/s41560-019-0529-5>

## 3. Required equipment

- Full-spectrum light soaking chamber with UV-cutoff at 400 nm and black panel temperature control of 75°C
- UV exposure chamber with UV-A and UV-B exposure at 340 nm peak and black panel temperature control to 60 °C
- Thermal cycling chamber with upper and lower temperatures of 85°C and -40°C, respectively.
- Damp heat chamber with 85°C and 85 % relative humidity control.
- Humidity-freeze chamber with upper and lower temperature control of 85°C and – 40°C, respectively. And 85% relative humidity control.

## 4. Protocol Details

Figure 1 outlines version 0.0 of the accelerated stress testing protocol. Prior to any stress testing it is recommended the modules be characterized include visual inspection, preconditioning/ratio test, a performance characterization, and module characterization steps. Details of the preconditioning test can be found at <https://pvpact.sandia.gov/publications-and-protocols/> . While this test is still underdevelopment PACT recommends a performance characterization validation step using methods outlined here:



**Figure 4-1. Test flow for stress testing MHP modules**

The protocol is then divided into two testing legs: MHP focused and packaged-focused testing sequences. The package focused test is a modified test sequence from IEC 63209-1 sequence 3 . This test leg is designed to identify package failures such as delamination and moisture ingress. A pass/fail criteria is applicable as defined by IEC 61215-1:2021 clause 8, where no major visual defect is observed. An optional requirement for the inclusion of an evaporated calcium on polyethylene terephthalate substrate in the package, which can be used to identify moisture or oxygen ingress.

The MHP-focused test includes three (3) different stressor types: light and elevated temperature, UV exposure, and thermal cycling. Pass/fail of the test sequence is as defined in IEC 61215-1:2021 clause 7.2,3, where the maximum power drop shall be no more than 5 %. Additionally, there shall be no major visual defects such as bubbling or cracking.

Light and elevated temperature: 1-sun, 75 °C, 250kWh/m², UV-filtered light. Samples to be configured in short-circuit.

UV Exposure: 15 kWh/m² at AM1.5G spectrum. Total UV: 7.5 Wh/m² with UV intensity of 0.5 W/m²/nm @340 nm. Ambient temperature: 60 °C per IEC 61215-2:2021 MQT 10. Samples to be configured in short-circuit.

Thermal Cycling: 50 cycles, - 40 C to 85 C, per IEC 61215-2:2021 MQT 11 profile. No current injection.

Each test is repeated up to four times with characterization at each check point. The purpose of this cycled tests is to determine the appropriate test length for MHP modules.

## 5. Protocol Validation



This protocol still needs to be validated before it can be adopted more generally and will likely be adjusted as more data is collected. All test parameters and lengths will be optimized against field data collected on sister modules. PACT anticipates updating this document and protocol bi-annually with supporting data and modified procedures.



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